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BRIGHTNESS DISTRIBUTION IN THE LIMB ZONE OF MARS

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ABSTRACT

The results of photoelectric observations of Mars by the method of cross sections are presented. The observations were made in the Cassegrain focus of the 70 cm reflector at the Main Astronomical Observatory of the Academy of Sciences of the Ukrainian SSR. In the opposition of 1963, the brightness distribution along the apparent radius of the planet was traced up to $r = 0.97R_♂$. The data, averaged and corrected for turbulent scintillation of the image and for the finite size of the diaphragm ($D = 0''.35$), are tabulated. It was found that for $\lambda < 390$ nm the atmosphere of Mars possesses an appreciable true absorption, while for longer wavelengths scattering provides the main contribution.

The application of the techniques of photographic photometry for the investigation of the variation in brightness with angle of light incidence along the radius of the apparent disk of Mars does not yield the results hoped for, because it is necessary in this case to limit the distance from the center of the image to $r \leqslant 0.85R_♂$. /54*

The need has arisen for some alternative method of studying the brightness distribution along the radius of the planet, one that would first of all afford the possibility of securing information as to the variation in brightness at the edge of the image and, secondly, enhance the precision of the measurements

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*Numbers in the margin indicate pagination in the original foreign text.

significantly. This requirement, in our opinion, is well met by the method of photoelectric cross sections of the apparent disk of the planet. In fact, by using the diurnal motion of the planet as the mechanism for displacement of the electrophotometer diaphragm, we obviate the necessity of measuring the scale of the image. In processing the observations, it is sufficient to know the ephemeris diameter of the planet. At the same time, electrophotometric measurements ensure high precision on the part of the observations.

During the opposition of Mars in 1963, we used the indicated method to study the brightness distribution along the apparent diameter of the planet. The observations were made at the Cassegrain focus of the 70 cm reflector at the Main Astronomical Observatory of the Academy of Sciences of the Ukranian SSR (GAO AN USSR). The diaphragm of the photoelectric photometer subtended a circle with a diameter 0".35 in the celestial sphere. The radiation receptor was an EMI-9502 photomultiplier (355-600 nm) and an infrared photomultiplier (450-900 nm). A loop oscillograph was used for recording. Simultaneously, second markers were recorded from a contact chronometer as a means of checking the scale of the record. For the observations, we used light filters, whose effective wavelengths in combination with the photomultiplier photocathode are shown in the table.

$r/R_{♂}$ \ λ, nm	355	390	420	450	475	510	560	600	760	900
0.00	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
.40	0.965	0.981	0.983	0.977	0.971	0.960	0.951	0.943	0.951	0.958
.60	.892	.950	.951	.927	.906	.889	.874	.866	.870	.880
.80	.690	.842	.850	.801	.753	.710	.673	.652	.668	.679
.85	.589	.791	.794	.719	.682	.638	.550	.558	.581	.602
.90	.450	.702	.711	.637	.570	.519	.476	.447	.460	.470
.92	.369	.650	.659	.585	.526	.472	.420	.394	.403	.417
.94	.301	.569	.575	.511	.465	.406	.355	.336	.341	.349
.96	.208	.470	.475	.431	.388	.310	.275	.204	.261	.285
.97	.097	.331	.335	.299	.274	.250	.161	.107	.132	.148

/55

Since the main source of interference in such observations is turbulent scintillation of the image, we used observations made under the most favorable atmospheric conditions for the final processing. By fortuitous chance, one of the "favorable" dates happened to be 4 February 1963, the same day as the opposition of Mars. On this night, during which for two hours the zenith distance of Mars did not exceed 35°, we obtained a total of 40 to 50 cross sections for each light filter. Concurrently with the recording of the cross sections, we visually estimated the effective scintillation amplitude of the image, σ. On 4 February 1963, $\sigma = 0''.4$. The sections obtained for each light filter were averaged, then the resultant averaged curves were corrected for scintillation of the image and the finite size of the diaphragm. It was assumed at this time that the turbulent fluctuations fit a normal distribution. In view of the fact that, for the averaged curve, the effective time of observation for each point on the apparent disk was greater than the effective period of scintillation, the use of a normal distribution law is justifiable. The true brightness distribution along the diameter of Mars was ascertained from the following expression:

$$F(t) = \frac{1}{A} \int_{-\infty}^{+\infty} S(t-x)\, F(x)\, dx, \tag{1}$$

where F(t) and F(x) are the observed and true distributions, respectively. The kernel $S(t - x) = S(t')$ in the integral equation (1) is physically interpreted as the brightness distribution for a point source under the given experimental conditions (diaphragm radius R and effective scintillation amplitude σ). The function $S(t - x)$ is found from the expression

$$S(t') = A \int_{-\infty}^{+\infty} \sqrt{R^2 - (t'-y)^2} \cdot e^{-\frac{y^2}{2\sigma^2}}\, dy, \tag{2}$$

where the first factor in the integrand takes into account the smearing of the /56 brightness distribution pattern due to the finite diameter of the diaphragm, the second factor accounts for turbulent scintillation; A is defined by normalization.

The problem is solved in practice as follows.

From the known values of R and σ, $S(t')$ is determined according to Eq. (2). Equation (1) is solved by the method of successive approximations. The zeroth approximation in this case is the observed brightness distribution $F(t) = F_0(t)$, and the following auxiliary function is determined:

$$f_1(t) = \frac{1}{A}\int_{-\infty}^{+\infty} S(t-y)F(y)\,dy.$$

As a first approximation, we choose the distribution

$$F_1(t) = F_0(t) + [F(t) - f_1(t)].$$

For the nth approximation, we have

$$F_n(t) = F_{n-1}(t) + [F(t) - f_n(t)].$$

It is evident that the computation process is continued until we have $f_n(t) \equiv F(t)$.

The second approximation proved adequate in our case for reproduction of the true distribution.

It is important to note that during the observation period the direction of motion of the diaphragm was parallel to the Martian equator. The measurements performed on 4 February 1963 referred to the equatorial land regions bounded by the longitudes 310-180°. The results obtained relative to the brightness distribution along the radius of the disk of Mars are shown in the table.

We note, first of all, that at 600 nm the variation in brightness with angle of light incidence i closely follows a Lambert law. Toward smaller λ, the curvature of the corresponding curves diminishes to a minimum value at 420 nm, after which it gradually increases again, down to 390 nm. At 355 nm, the atmosphere of Mars has an appreciable true absorption. From 600 nm to 900 nm, a gradual decrease in curvature is observed. Reinforcing this with the fact that a similar behavior was observed on 23 January and 28 February 1963, we may justifiably assert the continuous presence in the Martian atmosphere of dust-particle scatterers about 1 μ in radius (as we had discovered earlier; see ref. 1). The data shown in the table, relating to the brightness distribution along the radius of Mars, should be of further use in determining the parameters of the Martian atmosphere by the application of appropriate theoretical relations.

We note, in conclusion, that if the values obtained in 1961 (ref. 2) for /57 the visible albedo ρ at the center of the Mars disk are assumed for every wavelength beginning with 420 nm, then for the limb ($r = 0.97R_{♂}$ or $i = 76°$) we will have

λ, nm	420	450	475	510	560	600
ρ	0,020	0,021	0,023	0,028	0,029	0,030

Although the measurements refer to the limb of Mars, at 600 nm and for the probable values of $\tau \leqslant 0.1$, the true surface will have a considerable influence on the measured value of ρ. The first term on the right-hand side of the equation

$$\rho_i = A f(i) e^{-2\tau \sec i} + B_i$$

for $A \approx 0.3$, $f(i) \approx 0.1$, $\tau \leqslant 0.1$, and $i = 76°$ will be at least 0.014, while $B_i \leqslant 0.016$. For 420 nm, $B_i \approx \rho_i$, whence it follows that the brightness of the atmospheric column in the interval 420-600 nm increases significantly with diminishing wavelength, hence scattering prevails over absorption in the visible region of the spectrum in the atmosphere of Mars.

REFERENCES

1. Koval', I. K. and A. V. Morozhenko. Astronomicheskiy Zhurnal, Vol. 39, pp. 65-72, 1962.

2. Didychenko, Ye. I., Koval', I. K. and A. V. Morozhenko. Izvestiya Glavnoy Astronomicheskoy Observatorii Akademii Nauk Ukrainskoy SSR (Izv. GAO AN USSR), Vol. 5, No. 1, pp. 47-67, 1963.

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